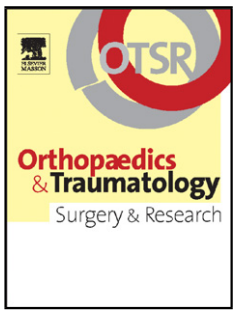
Medial Acetabular Wall Breach in Total Hip Arthroplasty - Is Full-Weight Bearing Possible?

Mandelli, Filippo ; Tiziani, Simon ; Schmitt, Jürgen ; Werner, Clément M L ; Simmen, Hans-Peter ; Osterhoff, Georg

Abstract: BACKGROUND A breach of the medial acetabular wall is a phenomenon seen frequently due to over-reaming during total hip arthroplasty (THA). The consequences of this issue are not fully understood particularly in cementless THA. A retrospective study was performed to answer whether: 1) immediate postoperative full-weight bearing in the presence of a medial acetabular wall breach after THA results in more short-term revisions of the acetabular component, 2) increases the risk for migration of the acetabular component? HYPOTHESIS Immediate full-weight bearing in the presence of a medial breach is not associated with an increased likelihood for acetabular-related revision surgery or migration of the cup. PATIENTS AND METHODS In this retrospective cohort study, consecutive patients (n=95; mean age 68±13 years; 67 female) who underwent THA with an uncemented acetabular component were identified and a retrospective chart review was performed (follow up 23±17 months, range 6 to79 months). The presence of a postoperative radiographic medial acetabular breach was documented and the need for revision surgery and the rate of acetabular component migration were assessed during follow-up. RESULTS Some extent of radiographic medial acetabular wall breach was seen in 26/95 patients (27%). With regard to the primary outcome, 2/95 patients (2%) required revision surgery during follow up. All revision surgeries occurred in the group without a medial breach (p=0.280) for causes related to the femoral or the head components. Persistent pain was present in 1/26 patients (3.8%) in the medial breach group and 8/69 patients in the control group (11.6%; p=0.436). In the radiographic follow up (n=81), there was no significant difference between the control group and the medial breach group with regard to cup migration (Δ ilio-ischial overlap (distance between the ilio-ischial line and a parallel line tangential to the acetabular cup on AP views): -0.5±0.9mm (range, -2.9 to 0.8) vs. -0.3±1.7mm (range, -1.9 to 2.2), Δ overlap tangent (defined as the distance between the two crossings of ilio-ischial line and the acetabular component on AP views): -2.2±6.1mm (range, -21.4 to 0.0) vs. 0.4±6.9mm (range, -6.2 to 17.6)). Similarly, according to variation in the ilio-ischial overlap distance between post-operative and follow-up on pelvic AP views, 0/56 hips (0%) had cup migration 5mm in the control group versus 1/25 (4%) in the medial breach cohort (p = 0.3). DISCUSSION In this retrospective observation of patients with immediate postoperative full-weight bearing after THA, a radiographic breach of the medial acetabular wall was not associated with an increased risk for short-term revision surgery or radiographic migration at follow-up. According to the findings of this study and in the light of previous biomechanical studies, there is no clear evidence for postoperative partial-weight bearing in case of a medial breach as far as the surgeon feels that the acetabular component is stable.

DOI: https://doi.org/10.1016/j.otsr.2018.04.020

Originally published at:
Mandelli, Filippo; Tiziani, Simon; Schmitt, Jürgen; Werner, Clément M L; Simmen, Hans-Peter; Osterhoff, Georg (2018). Medial Acetabular Wall Breach in Total Hip Arthroplasty - Is Full-Weight Bearing Possible? Orthopaedics Traumatology, Surgery Research (OTSR), 104(5):675-679.
DOI: https://doi.org/10.1016/j.otsr.2018.04.020



Title: Medial Acetabular Wall Breach in Total Hip Arthroplasty – Is Full-Weight Bearing Possible?

Author: Filippo Mandelli Simon Tiziani Jürgen Schmitt Clément M.L. Werner Hans-Peter Simmen Georg Osterhoff

PII: S1877-0568(18)30163-4
DOI: https://doi.org/doi:10.1016/j.otsr.2018.04.020
Reference: OTSR 2039

To appear in:

Received date: 26-1-2018
Accepted date: 26-4-2018

Please cite this article as: Mandelli F, Tiziani S, Schmitt J, Werner CML, Simmen H-P, Osterhoff G, Medial Acetabular Wall Breach in Total Hip Arthroplasty – Is Full-Weight Bearing Possible?, *Orthopaedics and Traumatology: Surgery and Research* (2018), https://doi.org/10.1016/j.otsr.2018.04.020

Original article

Medial Acetabular Wall Breach in Total Hip Arthroplasty – Is Full-Weight Bearing Possible?

Filippo **Mandelli** [a], Simon **Tiziani** [a], Jürgen **Schmitt** [a], Clément M.L. **Werner** [a], Hans-Peter **Simmen**[a], Georg **Osterhoff** [a,*]

a Department of Trauma, University Hospital of Zurich, Raemistrasse 100, 8091 Zurich, Switzerland

*** Corresponding author:** Georg Osterhoff, Department of Trauma University Hospital Zurich
Rämistrasse 100 8091 Zürich, Switzerland
Tel: +41 44 255 4190
Fax: +41 44 255 4406
Email: georg.osterhoff@usz.ch

Abstract

Background:

A breach of the medial acetabular wall is a phenomenon seen frequently due to over-reaming during total hip arthroplasty (THA). The consequences of this issue are not fully understood particularly in cementless THA. A retrospective study was performed to answer whether: 1) immediate postoperative full-weight bearing in the presence of a medial acetabular wall breach after THA results in more short-term revisions of the acetabular component, 2) increases the risk for migration of the acetabular component?

Hypothesis:

Immediate full-weight bearing in the presence of a medial breach is not associated with an increased likelihood for acetabular-related revision surgery or migration of the cup.

Patients and Methods:

In this retrospective cohort study, consecutive patients (n=95; mean age 68±13 years; 67 female) who underwent THA with an uncemented acetabular component were identified and a retrospective chart review was performed (follow up 23±17 months, range 6 to79 months). The presence of a postoperative radiographic medial acetabular breach was documented and the need for revision surgery and the rate of acetabular component migration were assessed during follow-up.

Results:

Some extent of radiographic medial acetabular wall breach was seen in 26/95 patients (27%). With regard to the primary outcome, 2/95 patients (2%) required revision surgery during follow up. All revision surgeries occurred in the group without a medial breach (p=0.280) for causes related to the femoral or the head components. Persistent pain was present in 1/26 patients (3.8%) in the medial breach group and 8/69 patients in the control group (11.6%; p=0.436). In the radiographic follow up (n=81), there was no significant difference between the control group and the medial breach group with regard to cup migration (Δ ilio-ischial overlap (distance between the ilio-ischial line and a parallel line tangential to the acetabular cup on AP views): -0.5±0.9 mm (range, -2.9 to 0.8) vs. -0.3±1.7 mm (range, -1.9 to 2.2), Δ overlap tangent (defined as the distance between the two crossings

of ilio-ischial line and the acetabular component on AP views): -2.2±6.1 mm (range, -21.4 to 0.0) vs. 0.4±6.9 mm (range, -6.2 to 17.6)). Similarly, according to variation in the ilio-ischial overlap distance between post-operative and follow-up on pelvic AP views, 0/56 hips (0%) had cup migration ≥ 5mm in the control group versus 1/25 (4%) in the medial breach cohort (p = 0.3).

Discussion:

In this retrospective observation of patients with immediate postoperative full-weight bearing after THA, a radiographic breach of the medial acetabular wall was not associated with an increased risk for short-term revision surgery or radiographic migration at follow-up. According to the findings of this study and in the light of previous biomechanical studies, there is no clear evidence for postoperative partial-weight bearing in case of a medial breach as far as the surgeon feels that the acetabular component is stable.

Level of Evidence: IV, Retrospective cohort study.

Key Words: Acetabular component; bone defect; medial breach; partial weight-bearing; total hip arthroplasty; total hip replacement.

1. Introduction

Reaming of the acetabulum is one of the key steps in THA [1,2]. Over-reaming or reaming to medially can cause a bone defect in the medial wall of the acetabulum. It remains unclear, however, whether this determines a higher risk of implant dislocation or periprosthetic fractures [3–5]. Too medial positioning of the acetabular cup with a medial breach may lead to a secondary migration of the implant, implant impingement, pain and sometimes revision surgery because of a possible weakness of the construct due to excessive removal of medial acetabular wall.

Usually, patients can be allowed full-weight bearing after THA [6, 7], but recent biomechanical studies concluded that a medial wall breach of 2 cm is associated with 26% decrease in load-to-failure of acetabular components in human cadavers [8] and a lower load to failure in canine acetabula [9]. However, the authors concluded that this difference was not clinically relevant since the applied breaking forces exceeded the normal physiologic loads in the dog during the gait. Neither of these findings has been confirmed in vivo.

What remains unclear is the relevance of a medial defect and how it should influence our intra-operative and post-operative strategy, since the majority of the stability of the acetabular component is determined by contact with the acetabular rim [10]. There is little evidence regarding the best surgical solution in case of a medial wall breach during hip total arthroplasty. Salvati et al. [11] stressed the importance of an intact acetabular medial wall and, in case of a defect, suggested immediate support by intraoperative bone grafting. Other solutions are acetabular revision cages and acetabular line-to-line cups with screw fixation and many surgeons recommend postoperative partial weight-bearing. At the authors' institution, no intra-operative repair of the defect nor a change of the postoperative rehabilitation protocol with immediate full weight-bearing is performed as long as the cup intra-operatively shows to be stable under direct manipulation. Particularly, it remains unclear whether protected weight-bearing is really needed in patients with a medial breach after THA. Therefore we performed a retrospective study to investigate whether immediate postoperative full-weight bearing in the presence of a medial acetabular wall breach after THA increases the risks for complications related to the acetabular component. The questions to be answered by this study were:

Does immediate postoperative full-weight bearing in the presence of a medial acetabular wall breach after THA: 1) result in more short-term revisions of the acetabular component? 2) increase the risk for migration of the acetabular component? Our hypothesis was that there is no increased likelihood for acetabular-related revision or migration of the cup with immediate full-weight bearing in the presence of a medial breach.

2. Materials and Methods

2.1 Patients

This retrospective cohort study was carried out in accordance with the local institutional ethics committee's terms of reference (Kantonale Ethikkommission Zürich, Switzerland. KEK-ZH-Nr. 2014-0557). Consecutive patients aged more than 18 years who underwent THA at a university trauma center between 10/2008 and 04/2016 were identified by a search of the hospital's database and a retrospective chart review was performed (n = 287). Patients with a cemented acetabular component (n = 101), a preoperative *Coxa protrusio* (n = 5) [12], or a follow up of less than 6 months (n = 81), and patients who underwent THA through an approach other than an anterior approach (n = 5) were excluded (Figure 1). Final analysis was performed in 95 patients (mean age 68 ± 13 years, range 39 to 92 years; 67 female), baseline characteristics are provided in Table 1. The mean follow up for all patients was 23 months ± 17 months (range, 6 to 79 months).

2.2 Methods

The indication for THA was a femoral neck fracture in 73/95 patients (76.8 %, 69 primary and 4 after internal failed fixation), primary or secondary (after acetabular fractures) osteoarthritis of the hip in 19 patients, and idiopathic femoral head necrosis in three patients.

All patients received the same acetabular component (Versafit CC Trio, Medacta International SA, Switzerland) and were operated through a minimal-invasive anterior (modified Smith-Petersen) approach by one of three board-certified orthopaedic surgeons trained with this approach. The used acetabular component with an elliptical shape and 0.7 mm diameter circular retaining splines had a titanium and hydroxyapatite coating. Cup size was chosen 4 mm larger than the femoral head. The

mean cup size in the medial breach group was 51±3 mm (range, 48 to 58 mm) and 52±3 mm (range, 48 to 60 mm) without medial breach. After impaction, cup anchorage was tested by pulling with a strong forceps. Reaming was performed under fluoroscopic imaging and it was tried to ream medially until touching Kohler's tear drop and cranially until bleeding from the subchondral bone was seen [2,13]. No screws were used for additional fixation of the acetabular cup. The femoral component (Quadra, Medacta International SA, Switzerland) was cemented in patients aged over 65 years (59/95 patients, 62.1 %), otherwise cementless stems were used if sufficient bone stock was present [14]. Femoral head sizes of 28 mm and 32 mm were used. Postoperatively, all patients were allowed to immediately full-weight bear but were given crutches for balance and gait stability.

2.3 Methods of assessment

The primary endpoint was the need for revision surgery of the acetabular component, excluding exchange of the polyethylene inlay. In addition, the presence of persisting pain at latest follow-up was documented. This was obtained through a retrospective chart review.

Secondary endpoint was radiographic migration. Conventional digitalized AP radiographs of the whole pelvis were taken by a MULTIX / Optitop 150/40/80 tube (Siemens, Munich, Germany; 71–90 kV, 25–40 mA). All radiographs were taken in a standardized fashion with a film-focus distance of 115 cm. Radiographic measurements were performed using the caliper tool of institutional imaging software (AGFA™ Impax viewer; AGFA, Mortsel, Belgium).

The presence of a *Coxa profunda* configuration on preoperative radiographs and of a medial acetabular wall breach on immediate postoperative radiographs was documented. Medial wall breach was defined as intersection of the prosthetic cup with the ilio-ischial line. A Coxa profunda was defined as the acetabular fossa being medial to the ilio-ischial line on the pelvis radiograph [15].

Three parameters were measured in order to quantify medial breach and medial protrusion on immediate postoperative radiographs of the whole pelvis: (1) the ilio-ischial overlap, that was defined as the distance between the ilio-ischial line and a parallel line tangential to the acetabular cup. (Figure 2). In case of no medial breach this value was negative and represented the minimal distance between the cup and the ilio-ischial line. (2) the length of overlap tangent, that was defined as the distance

between the two crossings of ilio-ischial line and the acetabular component (Figure 2). In case of no medial breach, this distance was zero. (3) the ilio-pectineal distance, that was defined as the minimal distance between the ilio-pectineal line and the acetabular component (Figure 3).

These measurements were repeated on follow-up radiographs at latest follow-up and compared to the postoperative measurement in order to assess potential migration. The difference between both measurements was calculated for each patient and reported as Delta (Δ) in Table 2. Based on previous radiometric studies around the hip, a change in ilio-ischial overlap of more than 3 mm was considered clinically relevant [16].

Initial postoperative radiographs were compared with the most current, correctly orientated film [17] that was archived in our patient database. Thirteen patients had to be excluded for the radiographic follow up because the initial postoperative radiograph was derotated or because there was no similarly orientated follow-up radiograph.

All measurements were performed three times by the same author (ST) and the mean was calculated. Intra class correlation coefficients (two-way mixed effects, consistency) were: postoperative ilio-ischial overlap: 1.0 (95% CI: 1.0 to1.0; $p < 0.001$), postoperative overlap tangent: 0.997 (95% CI: 0.995 to 0.998; $p < 0.001$), postoperative ilio-pectineal distance: 0.939 (95% CI: 0.911 to 0.960; $p < 0.001$), follow-up ilio-ischial overlap: 1.0 (95% CI: 1.0 to 1.0; $p < 0.001$), follow-up overlap tangent: 1.0 (95% CI: 0.999 to 1.0; $p < 0.001$), follow-up ilio-pectineal distance: 1,0 (95% CI: 0.999 to 1.0; $p < 0.001$).

2.4 Statistical Analysis

Primary endpoint was the need for revision surgery of the acetabular component. Prior to data acquisition, a sample size calculation was performed with a desired two-tailed Type I error of 0.05 and a power of 0.90. Based on literature data, we expected a 2-year baseline risk for acetabular component revision of 1 % [18]. The expected proportion of patients with a postoperative medial breach due to over reaming was 5 %. This revealed a minimum sample size of 39 patients for this study [19].

Further statistical analysis was done by the use of SPSS for windows 23.0 (SPSS, Chicago, Illinois, USA). Data are presented as frequencies (n) and means with the standard deviation (SD). To assess differences in means between the two groups, an independent-samples t-test was used for the

normally distributed continuous data and a Chi-Square test for categorical data. Missing data were reported as such for each outcome parameter. The level of statistical significance was set at $p < 0.05$.

3. Results

Some extent of radiographic medial acetabular wall breach was seen in 26/95 patients (27 %). These patients showed a mean postoperative radiographic ilio-ischial overlap of the acatebular component of 4.1 ± 2.6 mm (range, 0.7 to 10.2 mm), a mean overlap tangent length of 27.4 ± 8.0 mm (range , 13.3 to 44.5 mm), and a distance between acetabular component and ilio-pectineal line of 5.9 ± 3.4 mm (range, 0.5 to 11.0). Patients without a medial wall breach showed a mean postoperative radiographic ilio-ischial overlap of the cup of -2.4 ± 2.4 mm (range, -9.2 to 0.0 mm) and a distance between acetabular component and ilio-pectineal line of 10.1 ± 3.8 mm (range, 2.0 to 16.5), as there was no ilio-ischial overlap of the cup in the no breach group, there was no tangent to measure.
A postoperative medial acetabular breach was more frequently found in women (Chi-Square, p=0.001) and patients with a preoperative Coxa profunda (Chi-Square, p=0.031, Table 2).

With regard to the primary outcome, 2/95 patients (2.1 %) required revision surgery or intervention during follow-up. All revision surgeries occurred in the group without a medial breach (Chi-Square, p = 0.280). These comprised one head change to a larger head due to recurrent dislocation (at 2.5 months after index surgery), and one change of the femoral component due to an early shaft subsidence after a fall (at 3 weeks after index surgery). One additional patient (1/95, 1.1 %) required closed reduction of an early dislocation (at 21 days after index surgery) with the further follow-up being uneventful (in total the rate of dislocation was 2/95 (2.1%) one requiring bearing component exchange and one treated by reduction). There was no revision surgery for the acetabular cup. Persistent pain was present in 1/26 patients (3.8 %) in the medial breach group and 8/69 patients in the control group (11.6 %) (Fisher's Exact, p = 0.436). Seven of 9 patients (77.7 %) with persistent pain had uncemented femoral components.

In the radiographic follow up (n = 81), most patients showed subtle changes of the three radiographic parameters in terms of migration but the amount of these changes were not different

between the two groups (Table 3). With regard to the ilio-ischial overlap distance between post-operative and follow-up on pelvic AP views, 0/56 hips (0%) had cup migration ≥ 5mm in the control group versus 1/25 (4%) in the medial breach cohort (p = 0.3).

4. Discussion

While component oversizing and osteoporosis are well known risk factors for acetabular fractures there is still debate whether a medial wall defect could trigger postoperative migration of the acetabular cup or the occurrence of periprosthetic acetabular fractures. The aim of this study was to investigate the relation between medial acetabular wall breach and complications related to the acetabular component after a total hip arthroplasty in a cohort that was allowed immediate full-weight bearing. Medial breach was intent as the protrusion of the acetabular component beyond the Kohler's line. In this cohort, there was radiographic evidence of medial breach of the acetabular cup in 1/4 of the patients, which is a relevant finding. However, a radiographic medial breach was not found to be correlated with an increased risk for secondary migration, dislocation, fractures or pain. None of the revision surgeries that we performed occurred in the study group and all were limited to the shaft component.

This is consistent with the findings of the aforementioned biomechanical studies that showed failure of acetabular components implanted in cadaver pelvises with a medial breach only with loads beyond physiological thresholds [8–10]. It is known, that the hip contact forces in an acetabulum of a 75 kg- individual range from 1543 N to 2116 N during routine activities [20]. In their biomechanical cadaver study, Martin et al. [8] reported fractures of the acetabulum after THA with loads of mean 4221 N in a group with a 2 cm medial defect. Hence, there is a great margin of safety between routine in vivo forces and the point of failure. However, it was also shown that the peak contact forces may raise to 3600 N in a patient with disturbed gait patterns [21] and up to 5300 N - 6400 N during stumbling [20]. These values may of course put the acetabular wall in danger and could lead to a fracture. Walking with crutches may avoid the frequency of stumbling in these patients and thereby limit the risk for peak forces acting on the acetabular component - whether the patient is allowed to fully weight-bear or not. In fact, it is known from complex primary and hip revision surgery that

intentionally breaching the medial wall by using the "medial protrusion technique" is not associated with increased complications related to the acetabular component [22].

The radiographic analysis of the secondary outcome migration was conducted on plain x-rays, limiting it to a bidimensional view with the related projection artefacts. This may lower the accuracy of detecting a defect of the lamina quadrilateral, meaning that some of the patients where a medial breach was noticed, may not have true bone defects and could be false positive cases. This is supported by the high rate of medial breach that we found postoperative. However the interruption of the Kohler's Line in pelvis antero-posterior x-rays is widely accepted as the standard to define a radiological defect of the medial acetabular wall. Furthermore, a plain x-ray is usually the first and commonly the only imaging modality available prior and after surgery. In the light of the lack of a late migration in all the patients with an interruption of the ilio-ischial line, the potential inclusion of false positive cases does not affect the clinical relevance of our results.

According to the findings of this study and in the light of previous biomechanical studies, there is no clear evidence that there is a need to reconstruct an intraoperative acetabular medial wall breach during a primary THA as far as the surgeon feels that the acetabular component is stable under direct manipulation. This could be explained by the fact that the majority of the stability of the acetabular component is determined by the contact in the equatorial area. In the investigated cohort, all patients with a medial breach were allowed to full-weight bear and this did not result in an increased rate of acetabular related complications

The limitations of this study are inherent with its retrospective study design. A follow-up of 6 months may be considered short in THA. However, in case of diminished anchorage of the acetabular component due to a medial breach, a cup-related complication or migration will most likely occur within the first three months under immediate full-weight bearing. There may be small alterations of the biomechanics of the hip due to the medialization that could affect the longevity of the implants. This would require a follow-up several years, however. Measuring migration of the acetabular in the context of a medial wall breach has not been described previously in the literature. The only well-validated techniques for radiometric around the hip joint deal with natural hips [16]. We tried to compensate for this by the use of three different measurement methods. All three techniques showed

an excellent intra-observer reliability. However, the large ranges of the changes in overlap tangent length and ilio-pectineal distance (Table 3) indicate that overlap tangent length and ilio-pectineal distance seem vulnerable to even small rotational errors when obtaining the radiograph. In contrast, the ilio-ischial overlap technique showed a small variance of the delta-values and, hence, seems to be a reliable method. Radiological follow-up included conventional radiographs only. Hence, occult fractures may have been undetected. As this study was performed in an orthopaedic trauma center, a femoral neck fracture was the reason for THA in the large majority in this study's population. Even though there was no data available on the bone mineral density of all patients, there is an increased likelihood of higher age and impaired bone quality in the investigated cohort when compared to the average THA patient. Consistent with this, women – having a higher risk for impaired bone quality by gender – were more likely to sustain a medial breach in our study. This may be a potential bias of this study but also indicates that there is no increased risk for acetabular cup related complications with an intraoperative medial breach even in elderly patients with fragile bone. On the other hand, the impaired quality of bone may be an explanation for the rather high rate of revision surgery related to the femoral component (2.1 %). The primary outcome, however, was not of radiographic nature. Radiographic migration may be an indirect indicator for later pain and complications. The endpoint that is truly relevant from a patient's perspective, though, is the need for revision surgery – especially in a cohort of mainly elderly patients as seen in this study. Elderly patients need to get mobilized with early full-weight bearing as they often cannot follow partial weight-bearing directions. In this study, the acetabular component seemed not at risk for revision in the presence of a medial breach - even with immediate full-weight bearing.

5. Conclusion

In this retrospective observation of cohort of patients with immediate postoperative full-weight bearing after THA, a radiographic breach of the medial acetabular wall was not associated with an increased risk for revision surgery, pain or, radiographic migration at follow-up.

Conflicts of interest: Georg Osterhoff has given paid lectures for Medtronic and Stryker. The other authors declare that they have no competing interests. There was no external funding for this study.

Funding sources:

Authors' Contribution

Table 1 Baseline characteristics

	No Breach	Medial Breach	*p*
N	69	26	
Follow Up [months]	24 ± 18 (6 to 71)	21 ± 14 (6 to 65)	0.357[a]
Age [years]	67 ± 13 (39 to 86)	70 ± 13 (42 to 92)	0.211[a]
Gender [female]	42 (60.9 %)	25 (96.2 %)	0.001[b]
Coxa profunda	23 (33.3 %)	15 (57.7 %)	0.031[b]

[a] T-test. [b] Chi-Square test. Data is presented as mean ± standard deviation (range) or frequencies (percentage).

Table 2 Relationship between gender and preoperative *Coxa profunda*

	Normal hip	**Coxa profunda**	Total	***p***
N	57	38		0.017
Female	35 (52.2 %)	32 (47.8 %)	67	
Male	22 (78.6 %)	6 (21.4 %)	28	

Data is presented as frequencies (percentage).
Chi-Square test (gender vs. *Coxa profunda*): p = 0.017.

Table 3 Radiographic Follow Up

	No Breach	Medial Breach	*p*
N	56	25	
Δ ilio-ischial overlap [mm]	- 0.5 ± 0.9 (-2.9 to 0.8, 0 hip, 0 hip)	- 0.3 ± 1.7 (-1.9 to 2.2, 0 hip, 1 hip)	0.548 [a]
Δ overlap tangent [mm]	2.2 ± 6.1 (0.0 to 21.4, 1 hip, 8 hips)	0.4 ± 6.9 (-6.2 to 17.6, 6 hips, 9 hips)	0.092 [a]
Δ ilio-pectineal distance [mm]	- 0.7 ± 1.5 (-2.3 to 8.1, 1 hip, 1 hip)	0.4 ± 0.9 (-1.0 to 2.4, 0 hip, 0 hip)	0.424 [a]

Data is presented as mean ± standard deviation (range, number of patients with a $\Delta \geq 3$ mm and < 5 mm, number of patients with a $\Delta \geq 5$ mm).[a] T-test. Δ= DELTA / difference between absolute measures on the postoperative and the follow-up radiograph. Thirteen patients had to be excluded for the radiographic follow up because the initial postoperative radiograph was derotated or because there was no similarly orientated follow-up radiograph.

References

1. Boisgard S, Descamps S, Bouillet B. Complex Primary Total Hip Arthroplasty: Complex primary total hip arthroplasty. Orthop Traumatol Surg Res 2013; 99: S34-42.
2. Meermans G, van Doorn J, Kats JJ. Restoration of the centre of rotation in primary total hip arthroplasty. The influence of acetabular floor depth and reaming technique. Bone Joint J 2016;98:1597–1603.
3. Berry DJ, Lewallen DG, Hanssen AD, Cabanela ME. Pelvic discontinuity in revision total hip arthroplasty: Pelvic discontinuity in revision total hip arthroplasty. J Bone Joint Surg Am 1999;81:1692–1702.
4. Kim YS, Callaghan JJ, Ahn PB, Brown TD. Fracture of the acetabulum during insertion of an oversized hemispherical component. J Bone Joint Surg Am 1995;77:111–117.
5. Sharkey PF, Hozack WJ, Callaghan JJ, et al. Acetabular Fracture associated with cementless acetabular component insertion. A Report of 13 Cases. J Arthroplasty 1999;14:426–431.
6. Markmiller M, Weiss T, Kreuz P, Rüter A, Konrad G. Partial weightbearing is not necessary after cementless total hip arthroplasty. A two-year prospective randomized study on 100 patients: Partial weightbearing is not necessary after cementless total hip arthroplasty. A two-year prospective randomized study on 100 patients. Int Orthop 2011;35:1139–1143.
7. Tian P, Li ZJ, Xu GJ, Sun XL, Ma XL. Partial Versus early full weight bearing after uncemented total hip arthroplasty. A meta-analysis. J Orthop Surg Res 2017;12:31. doi: 10.1186/s13018-017-0527-x.
8. Martin CT, Heiner AD, Baer TE, Pugely AJ, Noiseux NO. Protrusio after medial acetabular wall breach in total hip arthroplasty. Iowa Orthop J 2015;35:99–107.
9. Margalit KA, Hayashi K, Jackson J, et al. Biomechanical evaluation of acetabular cup implantation in cementless total hip arthroplasty. Vet Surg 2010;39:818–823.
10. Hadjari MH, Hollis JM, Hofmann OE, Flahiff CM, Nelson CL. Initial stability of porous coated acetabular implants. The effect of screw placement, screw tightness, defect type, and oversize implants. Clin Orthop Relat Res 1994;307:117–123.

11. Salvati EA, Bullough P, Wilson PD. Intrapelvic Protrusion of the acetabular component following total hip replacement. Clin Orthop Relat Res 1975;111:212–227.

12. Baghdadi YMK, Larson AN, Sierra RJ. Restoration of the hip center during tha performed for protrusio acetabuli is associated with better implant survival. Clin Orthop Relat Res 2013;471:3251-9..

13. Bonnin MP, Archbold PHA, Basiglini L, Fessy MH, Beverland DE. Do we medialise the hip centre of rotation in total hip arthroplasty? Influence of acetabular offset and surgical technique. Hip Int 2012;22:371–378.

14. Hailer NP, Garellick G, Kärrholm J. Uncemented and cemented primary total hip arthroplasty in the swedish hip arthroplasty register. Acta Orthop 2010;81:34–41.

15. Sotelo-Garza A, Charnley J. The results of Charnley arthroplasty of hip performed for protrusio acetabuli. Clin Orthop Relat Res 1978;132:12–18.

16. Schofer MD, Pressel T, Heyse TJ, Schmitt J, Boudriot U. Radiological Determination of the anatomic hip centre from pelvic landmarks. Acta Orthop Belg 2010;76:479–485.

17. Tannast M, Zheng G, Anderegg C, et al. Tilt and rotation correction of acetabular version on pelvic radiographs. Clin Orthop Relat Res 2005;438:182–190.

18. Hooper GJ, Rothwell AG, Stringer M, Frampton C. Revision following cemented and uncemented primary total hip replacement. A seven-year analysis from the New Zealand joint registry. J Bone Joint Surg Br 2009;91:451–458.

19. Hulley SB, Cummings SR. Designing clinical research an epidemiologic approach. Philadelphia, PA: Lippincott Williams & Wilkins, 2013

20. Bergmann G, Deuretzbacher G, Heller M, et al. Hip contact forces and gait patterns from routine activities. J Biomech 2001;34:859–871.

21. Bergmann G, Graichen F, Rohlmann A. Hip Joint loading during walking and running, measured in two patients. J Biomech 1993;26:969–990.

22. Eskildsen SM, Wilson ZJ, McNabb DC, Olcott CW, Del Gaizo DJ. Acetabular reconstruction with the medial protrusio technique for complex primary and revision total hip arthroplasties. J Arthroplasty 2017;32:3474–3479.

Figure legends

Figure 1: Patient selection flowchart.

Figure 2: Radiographic measurements of the medial acetabular breach on AP pelvis views: ilio-ischial overlap and overlap length. * The ilio-ischial overlap was defined as the distance between the ilio-ischial line and a parallel line tangential to the acetabular cup on AP views of the whole pelvis. † The length of overlap tangent was defined as the distance between the two crossings of ilio-ischial line and the acetabular component on AP views of the whole pelvis.

Figure 3 Radiographic measurements of the medial acetabular breach: ilio-pectineal distance

The ilio-pectineal distance was defined as the minimal distance between the ilio-pectineal line the acetabular component on AP views of the whole pelvis.